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# End-users' opinion on living in multi-family nearly zero-energy buildings

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**Abstract.** The paper presents the findings on end-users' experiences and expectations about living in multi-family Nearly Zero-Energy Buildings (NZEBs). The survey in four European countries (Slovenia, Italy, Denmark and Germany) was part of EU Horizon 2020 project CoNZEBs (2017-2019) and addressed end-users living or thinking about living in multi-family NZEBs. Targeted end-users were living (as tenants or owners) in either ordinary buildings or in high performance buildings such as NZEBs (mandatory after 2020 according to Directive 2010/31/EU). In the survey, the following topics were addressed: the level of end-user's understanding of the NZEB concept, the source and quality of information on NZEB from the end-users' perspective, the importance of various apartment features for the end-users, perception of NZEB characterizing technologies, and decision triggers for living in NZEB. Concerns, doubts and eventual fears about living in NZEBs were studied to enable a tailored information for future end-users, to increase the demand for NZEB and beyond NZEB buildings and to improve their acceptability. To facilitate the living in NZEBs a guide for end-users was developed, explaining the "Myths" about NZEBs as well as presenting testimonials of current NZEB users in four participating countries.

## 1. Introduction

According to Directive 2010/31/EU [1] (EPBD recast) after 2020 all new buildings will have to comply with national requirements for nearly zero energy buildings (NZEB) (public buildings after 2018). Setting the national NZEB definition and its integration into the national building codes is the obligation and responsibility of each EU member state (MS). MSs prepared action plans for construction of early NZEBs before the full implementation of EC requirement on NZEBs after 2020/2018. In the transitional period, several technical concepts for construction of highly energy efficient buildings targeting the anticipated NZEBs performance levels were tested in practice [2]. According to the CoNZEBs project [3] NZEB like multi-family buildings (MFBs) built in various countries (German, Italy, Denmark and Slovenia) slightly differ in building's energy efficiency, in implemented technologies, in the share of RES used and above all in construction costs. Although the life cycle costing (LCC) of a NZEB building indicated the gap in costs between NZEB and regular buildings would become negligible after 2020/2018, the higher investment costs of NZEB remain a significant barrier for wider penetration of (early) NZEBs. In addition to that, early NZEBs are often associated with the lack of trust among end-users, due to complexity of systems and end-users' believes about various constraints regarding living in NZEBs. The CoNZEBs project aims at reduction of the above barriers for better penetration and



acceptance of new NZEB MFBs by studying in detail the costs reduction opportunities and by addressing end-users' attitude to NZEBs and most common myths and fears about living in NZEBs.

Deployment of NZEB market was studied [4] in ZEBRA2020 project; a survey of (inter-alia) end-users' related criteria in 18 countries showed rather good awareness/information/acceptance for NZEB, but low dependency of property value/rent on the energy performance (i.e. a minor impact of energy efficiency on customers' decision to buy/rent real estate, compared to other aspects like location, price and size of the real estate). COHERENO project analysed [5] home-owners' motives to choose for a NZEB-renovation of their house and concluded the leading motives are to reduce the energy consumption and to improve indoor comfort or health condition, while the evaluation of alternative renovation solutions and the trust in proper operation of all systems in NZEB remain the biggest challenges.

The research presented in this paper focused on the identification of end users' attitude to living in NZEBs and the comparison of the findings from different countries. The following research question was addressed: What are the multi-family building end-users' values and motives to take a decision for living in NZEB and what are their doubts about NZEBs? Understanding the doubts and fears as well as benefits of the end-users living and planning to live in NZEBs will enable the development of focused information activities for better acceptance of NZEBs among (current and future) tenants and owners.

## 2. Methodology

To perform a survey of end-users' attitude to living in NZEBs, a questionnaire was developed aiming at current and potential future users of NZEBs. The goal of the questionnaire was to learn about the opinion of end-users in existing and future multi-family NZEBs regarding their expectations and experiences with living in NZEBs, the decision triggers to move into NZEB, their potential doubts and fears about living in high performance buildings, technologies used in their buildings, the quality of life in such buildings, the eventual impact of NZEBs on the real-estate value.

The questionnaire had the list of common questions used in four participating countries and an additional set of specific questions adapted for each country (Germany, Italy, Denmark, Slovenia) so that they reflect the national situation of early NZEBs.

The common part addressed the following main topics: respondents' knowledge about NZEB, end-users' source and quality of information about NZEB, important apartment features for respondents, opinion on technologies characterizing most NZEBs, decision triggers for living in an NZEB, respondents age and tangible experiences with living in an energy efficient home, and concerns/doubts regarding living in high energy efficient buildings.

English questionnaire was available via the project web site [6], while the partners used adapted version translated into the national languages. Participating countries also adapted the methodology of information collection, so that Denmark used the online survey tool, Germany, Slovenia and Italy combined direct mailing (regular mail, e-mails) with printed questionnaire distributed to interested end-users during meetings and professional events, Italy also applied the online survey by using Google Forms and some face-to-face interviews. The survey was implemented by housing organisations in CoNZEBs and elaborated along the common template by research partners. The participation of end-users in the survey was voluntary and the interview results were anonymised.

## 3. Results and discussion

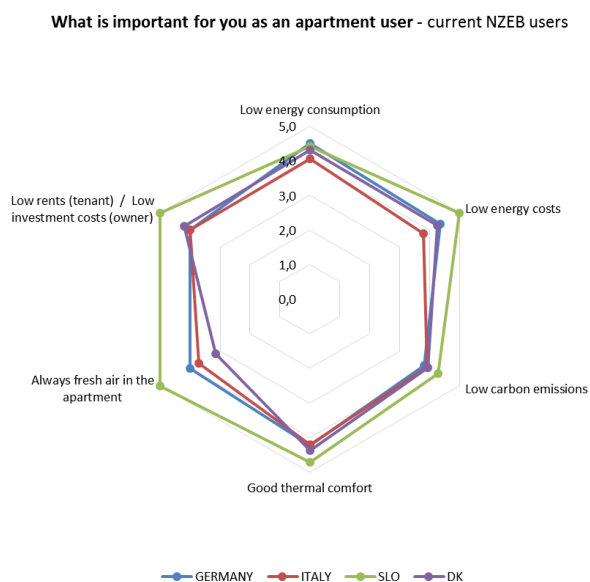
### 3.1. Response of end-users

Altogether, the interviews covered 293 end-users of which 112 are currently living in an NZEB and 181 are potential future users of NZEBs. In Germany altogether 46 respondents completed the questionnaire. 36 of the respondents already lived in an NZEB and the other 10 were potential future users of NZEBs. The Danish questionnaire targeted primarily the residents in apartments of social housing companies and at the same time solely residents in NZEB multi-family houses (all together 19 respondents participated in the survey). In Italy (Centre or South of Italy) 131 respondents completed the questionnaire, 50 of them were at the time living in NZEBs and the other 81 were non-NZEB users, i.e. potential future users of NZEBs. In Slovenia 90 potential and 7 current NZEBs users participated in the survey.

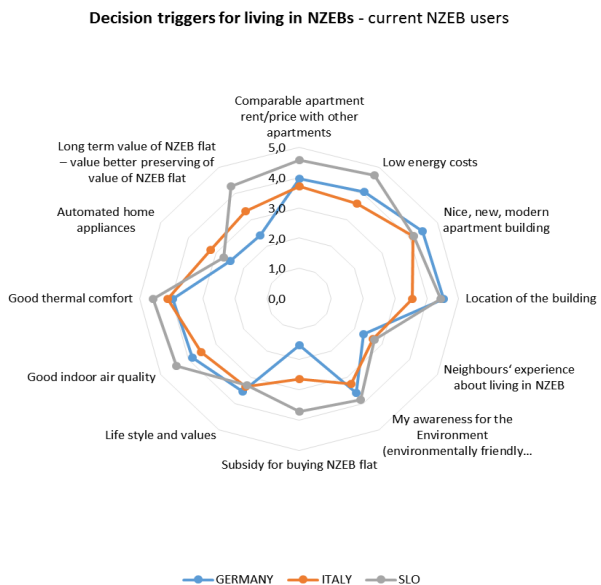
### 3.2. Common findings

The survey among current NZEB users on the importance of certain expectations about their flats showed (figure 1) that the apartment features "good thermal comfort" and "low energy cost" received the highest average importance (4.4 on 1 to 5 scale), they are followed by "low energy costs" and "low rents and/or low investment costs" (4.3), while "low carbon emissions" and "always fresh indoor air" have the lowest average importance (4.0). The biggest consensus on the opinion among four countries is about the importance of "low energy use" and "low carbon emissions" (average deviation 0.1), while the biggest deviation in opinion was detected in the importance of "always fresh indoor air" (0.5). For Slovenian NZEB users low rents and/or low investment costs (in case of owners' used apartments), low energy costs and always fresh indoor air are of utmost importance, noticeably higher than for end-users in Germany, Italy and Denmark. On the other hand, for Danish NZEB users "always fresh indoor air" has a bit lower priority; however, such an opinion may reflect the fact that Danish end-users live in NZEBs with mechanical ventilation with heat recovery and thus suffer less from low indoor air quality problems.

The decision triggers for moving into an NZEB were investigated in only three countries (figure 2); while in Danish survey, this question was omitted, as the participating housing organization rents-out only flats in NZEBs and the responses would not be equally relevant as in other countries. The highest average importance is given to the triggers "nice, new, modern apartment" (4.2) and "good thermal comfort" (4.2), and it is closely followed by the importance of "building location", "low energy costs" and "comparable rents and/or low investment costs (for owners' used flats)", all rated in average around 4.1. The consensus of countries on the most important triggers for moving into NZEB is good (i.e. low average deviation, from 0.1 to 0.4). The biggest shift in respondents' opinion per countries was detected in case of triggers "subsidy for buying NZEB flat" (incentives at the time only available in Slovenia) and "better preservation of NZEB flat value in long-term" (0.7 and 0.5). The latter may indicate that the consideration of the real-estate value preservation needs further analysis to be properly communicated as NZEB related benefit.



**Figure 1.** Importance of topics related to living in NZEBs for current NZEB users in Germany, Italy, Slovenia and Denmark (N=112) [7].



**Figure 2.** Decision triggers for living in NZEBs among current NZEB users in Germany, Italy and Slovenia (N=112) [7].

The survey addressed also respondents' experiences/opinion, concerns and doubts about living in NZEBs; the statements were collected in all participating countries. The common findings were classified in three groups, as follows:

Positive experiences based on the users' testimonials are: good sound insulation, silence in rooms when the windows are closed, less grid electricity needed due to the self-supply with PV panels, good quality of energy efficient components, good indoor climate, high quality of life in NZEB, very good thermal comfort and low energy consumption, raised awareness about energy efficient living, visibility of individual energy consumption through user's display.

Negative experiences: low indoor air humidity in winter and too hot in summer, frequent failures of technical equipment, frequent change of air filters needed, ventilation system in use when the outside temperature is very low, increase of investment and maintenance costs due to ICT equipment not important for regular use, problems with mechanical ventilation at lower outside temperatures.

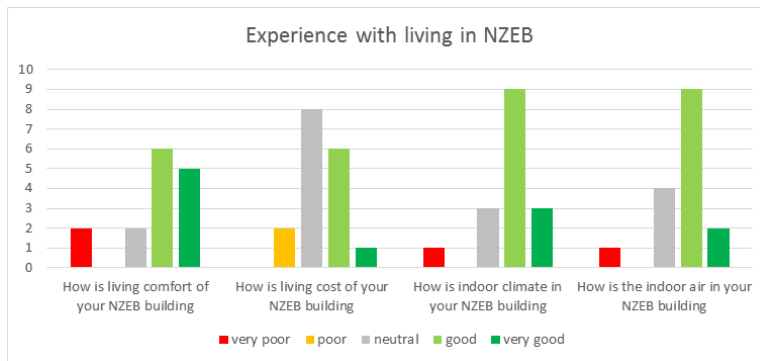
Concerns and doubts: use of NZEB in case of power outage or if supply of electricity from PV failed, possible feeling of distress and discomfort, high construction/renting costs, concerns about the quality of living indoors in NZEBs, smart systems cannot operate in case of a power outage, EM radiation due to many smart devices, too many devices may be burdensome for an average user.

From the end-users opinions about living in NZEBs some typical myths were extracted (like the myth 1: "too high level of building airtightness may cause the lack of fresh air" or the myth 2: "inadequate daylight levels due to small window size to cut energy losses and due to low light transmission of advanced glazing systems"). The myths were further explained and dispelled with professional clarification in a CONZEBs brochure for tenants and users of owners' occupied flats in NZEB multi-family buildings "Why nearly zero energy buildings are the right choice" [8].

### 3.3. Country specific findings

*3.3.1 Germany:* People seem to be well informed about NZEBs. The location of the flat and the financial constraints of the end-user are still predominant factors in taking a decision for a flat or against it. However, in the German survey, also some additional triggers for moving into NZEB were identified, such as life style and values, financial aspects of housing together with the energy costs, and triggers related to comfort (daylight, thermal comfort and indoor air quality). Among the important topics related to living in an apartment the indoor air quality, especially the dry air during winter, turned out to be an ongoing point of concern, and thus it should be properly addressed in order to prevent eventual negative associations with NZEBs. Concerning the height of the maintenance costs, the potential future and the current NZEB users in Germany clearly differ in their opinion on the topic. While 53% of the current NZEB users stated that the maintenance cost are lower in NZEBs, only 11% of the potential NZEB users support that opinion, the others expect to have higher maintenance costs if living in an NZEB. An interesting finding from German apartment users survey is also high ranked importance of healthy (non-hazardous) building materials used and a good access to daylight.

*3.3.2 Denmark:* In general, residents in Danish NZEBs are happy about living in a NZEB and 85% of them would choose a NZEB again if they had to move to another apartment. The residents in Danish social housing care a lot about the environment and expressed concern about their energy consumption, although they neither have exact knowledge about technical requirements of NZEBs and nor they are familiar with declared energy features in this kind of buildings. Mainly they connect NZEBs with the presence of solar PV panels that are visible from the street and with mechanical ventilation. The latter is an issue of concern, since it is visible in the flats and it is sometimes the source of noise and/or draughts in the flats. All multi-family NZEBs in Denmark are mechanically ventilated due to Danish Building regulations. Despite that, 37% of NZEB residents claim that they are opening the windows several times every week to ensure fresh air in their flats. Most of the residents (70%) who are opening the windows leave the windows open for more than 10 minutes. The indoor climate is considered as being good in the NZEBs as 75% answers either "good" or "very good" (figure 3). This might seem a little in contract to the fact that 69% evaluate the indoor air as being good or very good. The cost of living in a NZEB is slightly dominated by "neutral" (47%) to "good" or "very good".

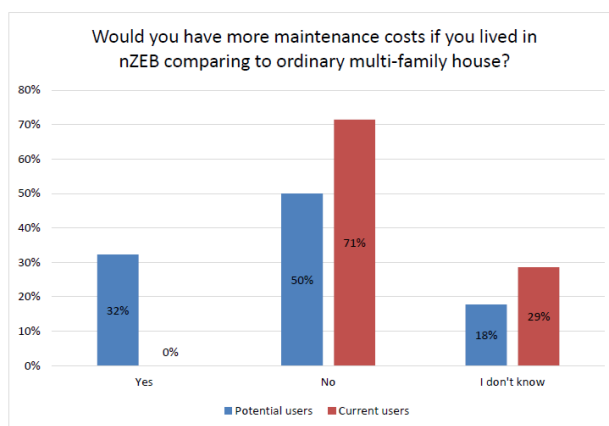


**Figure 3.** Experience with living in NZEBs, Denmark (N=19) [7].

**3.3.3. Italy:** Respondents are aware of the meaning of an NZEB, although they do not have an easy-to-access source of info about NZEBs. The analysis of the importance of decision triggers for living in NZEB in group of future NZEB users revealed that in general respondents highly value good thermal comfort, fresh air in the apartment and the use of healthy materials in buildings. However, potential NZEB users give more importance to low energy consumption, low energy costs, low carbon emissions and the use of renewable energy sources comparing to current NZEB users, who surprisingly consider more valuable the possibility of having good access to daylight, low rents and investment costs, respectively.

Regarding the maintenance costs, future NZEB users have more optimistic expectations, since 58 % of them believe that the maintenance costs might be lower in NZEBs, while only 28 % of current NZEBs users experience lower costs. In Italy most respondents living in NZEBs believe that for the optimal use of NZEBs technical expertise is useful, if not necessary. To be specific, one third of NZEB end-users (36%) recommend at least a basic knowledge of any technology installed, while others believe that NZEB buildings can be used without any technological knowledge, however a well-informed user can improve a building's performance.

**3.3.4 Slovenia:** Respondents in Slovenia seem well informed about NZEBs. For them low energy costs and low energy consumption are the most important, almost equally good thermal comfort, fresh air in the apartments and good access to daylight are valued. Residents also exposed some concerns, especially regarding technical buildings systems in NZEBs and the reliability of their performance. They do not appreciate too many electronic devices (automatization and control) in the apartment, as in their opinion this may worsen living conditions in NZEBs and at the end actually increase investment and maintenance costs. Mechanical ventilation and its summer performance is a frequent concern. Regarding the maintenance costs current and potential users have notable differences in their opinion, 32 % of potential users believe that they would have higher maintenance costs in NZEBs, while none of the current NZEB users experienced higher costs (figure 4).



**Figure 4.** Opinion on the height of maintenance costs in NZEBs comparing to ordinary multi-family building (potential NZEB users N=90, current NZEB users N=7, Slovenia) [7].

#### 4. Conclusion

The CoNZEBS survey on the opinion of (current and potential future) NZEB users about their expectations, fears and doubts regarding living in an NZEB covered 293 end-users of which 112 are currently living in an NZEB and 181 are potential future users of NZEBs. In Denmark and Germany NZEB users were prevailing respondents, while in Italy and Slovenia the group of potential future NZEB users was bigger.

According to the survey, the most common decision triggers for moving into an NZEB are connected to comfort and cost-related parameters, to incentives (subsidies) for buying an NZEB flat (available in some countries) and comparable prices/rents of flats in NZEBs with those of regular buildings. This indicates that the reduction of NZEB construction costs and consequently reasonable prices and rents can encourage the future growth of interest in NZEBs. Since low costs (rent, energy and maintenance costs) and low energy consumption are the most important element of satisfaction with a flat (figure 1), the costs reduction is an important way to increase attractiveness of NZEBs.

Respondents' concerns and doubts about living in NZEBs, as collected in CONZEBS survey, are in general: about the indoor air quality (especially the dry air in connection to ventilation systems with heat recovery during the winter), the longevity of advanced materials and life-time good performance technical building systems in NZEBs, the user friendliness of control systems and ICT appliances, and the cost benefit of numerous technologies and their actual usefulness.

Understanding end-users' attitude to NZEBs will enable the development of tailored activities for better acceptance of NZEBs and further market deployment.

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